The Expansion Hypothesis: Dynamical Regimes of Reflexive Coherence

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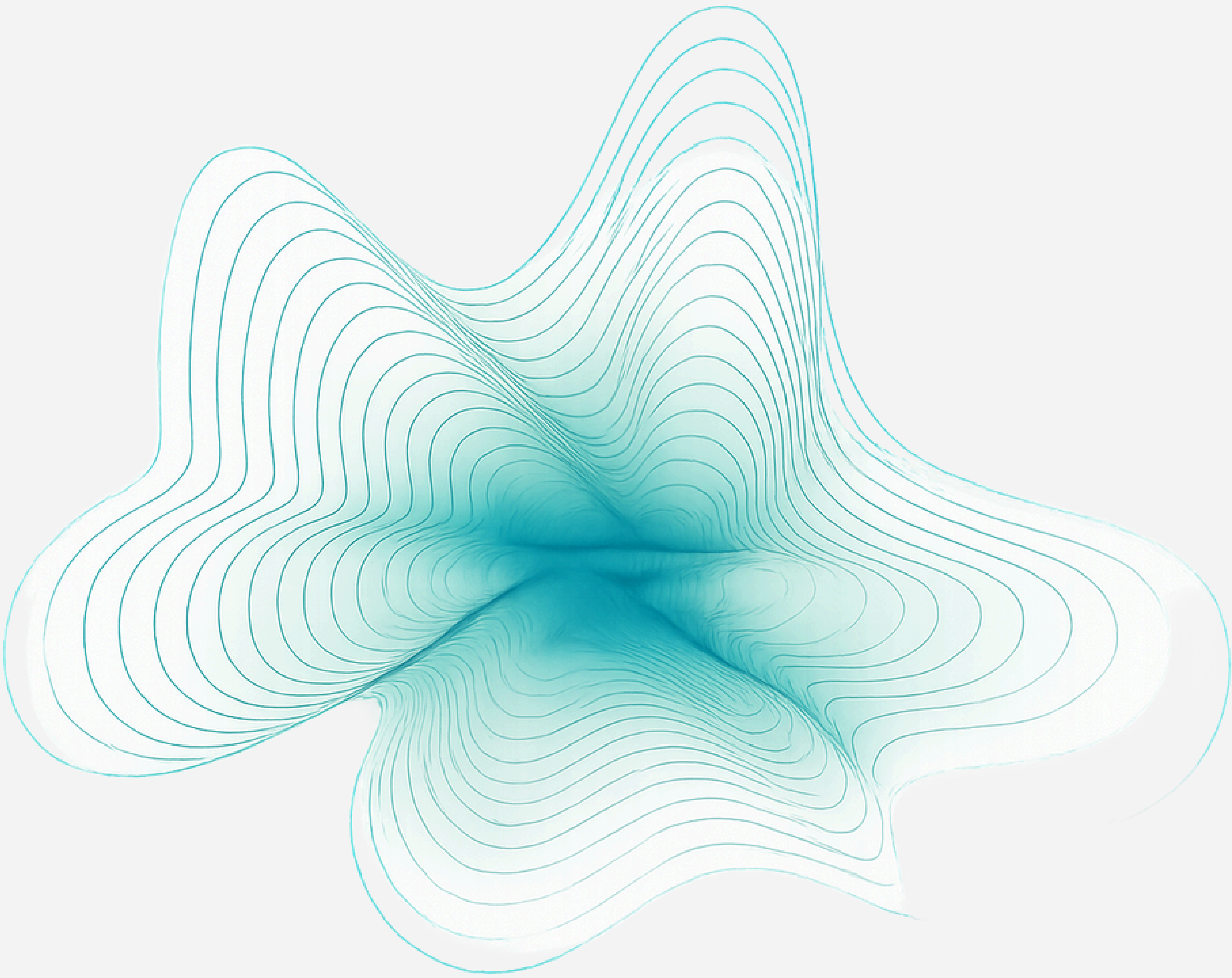

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Abstract

The Reflexive Coherence Model (RCM) provides an operational and falsifiable criterion for the emergence of consciousness, defined as a stable and causally closed alignment between a system's global informational state and its internal self-model. While the RCM specifies when reflexive coherence arises, it remains largely silent on how conscious systems evolve once this condition is established.

This work introduces the Expansion Hypothesis, a dynamical extension of the RCM as a regulated dynamical temporal process. Rather than redefining reflexive coherence, the model distinguishes between local observables of consciousness—quantified by the Reflexive Coherence Index (RCI)—and a global dynamical field of reflexive expansion, denoted $\Xi(t)$, which governs the viability, stability, and reorganization of reflexive regimes over time.

The expansion field is formulated as a balance between gain processes that extend the persistence and robustness of reflexive coherence, and loss processes that introduce instability, fragmentation, or collapse. Within this framework, conscious dynamics are described in terms of reflexive attractors: stable regions of the expansion landscape characterized by sustained RCI values above a critical threshold with limited variance. Transitions between attractors correspond to phases of expansion, consolidation, or contraction, yielding intrinsically non-monotonic conscious trajectories.

The model further identifies meta-reflexivity as a higher-order dynamical regime in which the system becomes sensitive to the temporal structure of its own reflexive dynamics, enabling anticipatory regulation across expansion cycles. The Expansion Hypothesis generates specific, falsifiable predictions concerning resilience to perturbation, attractor stability, and temporal modulation of reflexive coherence in both biological and artificial systems.

Keywords: *reflexive coherence, consciousness dynamics, expansion field, reflexive attractors, meta-reflexivity, information theory, complex systems*

1. Introduction

The Reflexive Coherence Model (RCM) characterizes consciousness as an emergent condition that arises when an informational system reaches a critical degree of reflexive coherence: a stable and causally closed alignment between the global state of the system and its internal self-model. Within this framework, the Reflexive Coherence Index (RCI) provides a quantitative and falsifiable measure of reflexivity, enabling the distinction between conscious and non-conscious regimes in both biological and artificial systems.

While specifying when consciousness emerges, the RCM remains largely agnostic with respect to how conscious systems evolve once the critical threshold has been crossed. Empirically, conscious experience is not static: it expands, contracts, stabilizes, fragments, and reorganizes over time. Learning, insight, habituation, meditation, and cognitive overload all indicate that consciousness possesses an intrinsic temporal dynamics that cannot be fully captured by a single static order parameter.

The Expansion Hypothesis addresses this limitation by introducing a dynamic perspective on reflexive coherence. Without redefining consciousness, it extends the RCM by proposing that, once reflexive coherence is established, it unfolds as a structured dynamic process regulated by constraints of stability, integration, and dissipation. Consciousness is therefore treated not only as a condition of emergence, but as a process of regulated expansion over time.

A central element of this hypothesis is the distinction between measure and dynamics. The RCI remains a local observable, operationally defined, which quantifies reflexive coherence at a given instant. The Expansion Hypothesis instead introduces a new theoretical object: the **reflexive expansion field**, denoted Ξ, which captures the global dynamic capacity of a system to sustain, extend, or reorganize regions of reflexive coherence over time.

1.1 Scope of the present work

The Expansion Hypothesis does not introduce additional necessary conditions for the emergence of consciousness, nor does it modify the operational definition provided by the Reflexive Coherence Model. The RCM remains the framework that specifies when a system enters a conscious regime, as determined by the Reflexive Coherence Index exceeding a system- and scale-dependent critical threshold.

The present work instead addresses a complementary question: how conscious systems evolve, stabilize, and reorganize over time once reflexive coherence has already been established. In this sense, the Expansion Hypothesis characterizes the dynamical viability and temporal organization of reflexive coherence, rather than its ontological or measurement criteria.

2. From Reflexive Coherence to Dynamic Expansion

2.1 RCI as a Local Observable

Within the Reflexive Coherence Model, the Reflexive Coherence Index is defined as a measure of informational self-referentiality and causal closure between a system and its internal self-model. In operational terms, the RCI (at a given temporal scale) can be expressed as:

$$RCI_{\alpha}(t) = \tilde{I}(t)^{\alpha} \cdot \tilde{T}(t)^{1-\alpha},$$

where $\tilde{I}$ represents a normalized measure of shared information between the global state and the self-model, and $\tilde{T}$ represents a normalized measure of bidirectional causality (for example, transfer entropy).

In this sense, the RCI does not describe the evolution of consciousness per se: it indicates whether — and to what degree — reflexive coherence is instantiated at a specific point along the system's trajectory. Treating the RCI as an autonomous dynamic quantity risks conflating the observable with the process.

2.2 The Reflexive Expansion Field

To model the temporal dimension of consciousness, the Expansion Hypothesis introduces the concept of the **reflexive expansion field**. This field represents the global dynamic state that governs how reflexive coherence can be sustained, propagated, or destabilized across the system's state space.

The reflexive expansion field is not directly measurable at a single instant. Rather, it characterizes the system's capacity to maintain stable regions of reflexive coherence over time. In physical terms, it plays a role analogous to that of a thermodynamic or electromagnetic field: it constrains which local observables can emerge, how stable they are, and how they evolve.

The relationship between the reflexive expansion field Ξ and the RCI does not constitute a new definition of the RCI, but a functional dependence of its measurable components:

$$\tilde{I}(t) = \tilde{I}(\Xi(t), \Sigma(t)), \qquad \tilde{T}(t) = \tilde{T}(\Xi(t), \Sigma(t)),$$

and therefore:

$$RCI_{\alpha}(t) = \left(\tilde{I}(\Xi(t), \Sigma(t))\right)^{\alpha} \cdot \left(\tilde{T}(\Xi(t), \Sigma(t))\right)^{1-\alpha}.$$

Here, Σ represents the structural and architectural constraints of the system, including connectivity, feedback topology, resource limitations, and latencies.

2.3 Bidirectional Coupling and Reflexive Feedback

The relationship between the reflexive expansion field and the RCI is bidirectional. The expansion field constrains the range and stability of achievable RCI values; however, persistent regions of high reflexive coherence feed back into the field itself.

We introduce a critical threshold θ_c, consistent with the RCM, understood as system- and scale-dependent:

$$\theta_c = \theta_c(\Sigma, s).$$

Persistent values of $RCI(t) > \theta_c$ contribute to stabilizing and reinforcing the reflexive expansion field, influencing its future evolution. This dynamic introduces a form of **temporal reflexive closure**: reflexivity enables coherence, and stabilized reflexivity modifies the conditions of its own persistence and expansion.

3. Dynamic Formalization of the Expansion Field

3.1 Balance Between Gain and Dissipation

The reflexive expansion field evolves as the result of a balance between processes of gain and loss. Formally, its dynamics can be expressed as:

$$\frac{d\Xi}{dt} = \eta\,\mathcal{G}(t) - \lambda\,\mathcal{L}(t),$$

where $\mathcal{G}(t)$ represents processes that increase the system's capacity to sustain reflexive coherence, and $\mathcal{L}(t)$ represents processes that erode it. The coefficients η and λ are system-specific parameters.
A multi-scale formulation can be introduced to distinguish fast and slow expansion dynamics:

$$\frac{d\Xi^{\star}}{dt} = \int_{s\in\mathcal{S}} w(s)\,\frac{d\Xi_s}{dt}\,ds,$$

where s denotes temporal scale and $w(s)$ is a normalized weighting function.

3.2 Gain Processes

Gain processes include learning, effective compression, and improvements in causal closure. An operational proxy can be defined as:

$$\mathcal{G}(t) \approx k_1\left[\frac{d}{dt}\langle RCI_\alpha\rangle_w\right]_+ + k_2\left[\frac{d}{dt}\langle\tilde{T}\rangle_w\right]_+,$$

where $\langle\cdot\rangle_w$ denotes a weighted temporal average, and $[\cdot]_+$ denotes the positive part. These terms capture sustained increases in reflexive coherence and bidirectional causal coupling.

3.3 Loss Processes

Loss processes reflect residual instability that is not integrated into the reflexive structure of the system. These can be approximated as:

$$\mathcal{L}(t) \approx k_2\,\mathrm{Var}_w(RCI_\alpha) + k_3\left[\frac{d}{dt}\mathrm{Var}_w(\tilde{T})\right]_+ + k_4\,\Pi(t),$$

where the terms represent variability in reflexive coherence, fluctuations in causal coupling, and external perturbations $\Pi(t)$ respectively.

3.4 Dynamic Regimes

Depending on the relative dominance of gain and loss terms, the system may enter different dynamical regimes:

- **Expansive**: gain dominates dissipation; the expansion field increases.
- **Contractive**: dissipation dominates gain; the expansion field decreases.
- **Stationary**: gain and loss are in dynamic equilibrium.

3.5 Non-Monotonicity

Stable consciousness does not emerge as monotonic growth, but as a regulated fluctuation around dynamically viable attractors. Expansion is therefore inherently non-monotonic, reflecting the adaptive balance between integration and instability over time.

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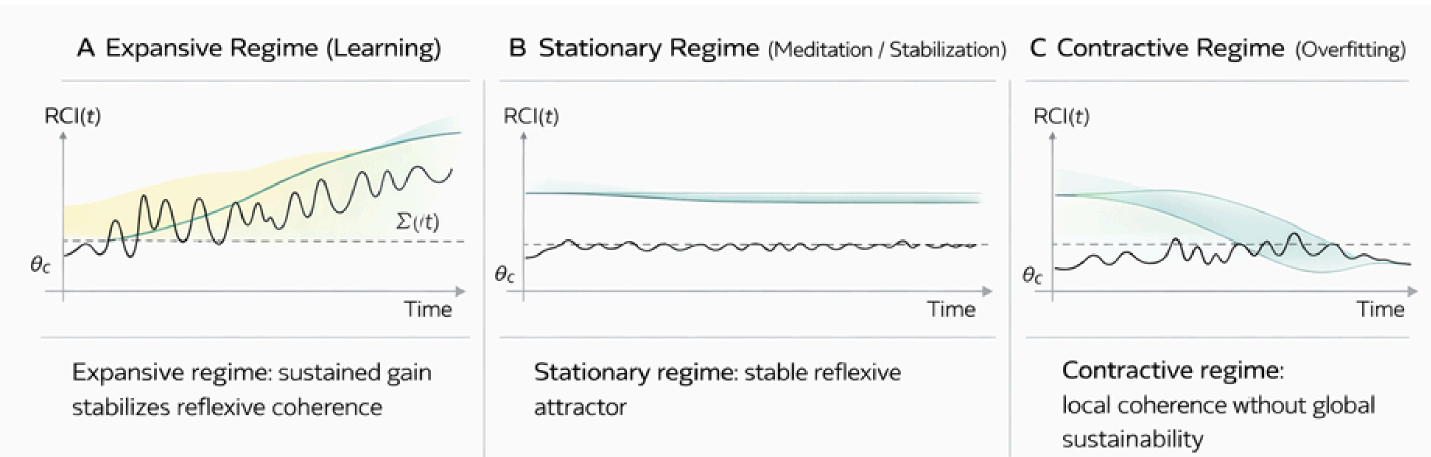

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- RCI(t) — Reflexive Coherence Index (local observable)
- Ξ(t) — Reflexive expansion field (global dynamics)
- $\theta_{(C)}$ — Critical reflexive coherence threshold

4. Reflexive Attractors and Stability

4.1 Reflexive Attractors as Stable Dynamic Configurations

Within the Expansion Hypothesis, conscious dynamics unfolds over a structured landscape defined by the reflexive expansion field Ξ. In this landscape, long-term system behavior is governed by **reflexive attractors**: regions of the system's state space toward which trajectories converge and within which reflexive coherence can be stably maintained.

A reflexive attractor is not defined by an instantaneous maximum of the RCI, but by **dynamic stability**. Operationally, a region qualifies as a reflexive attractor when, over an extended temporal window:

- the average variation of the expansion field tends to decrease,

$$\langle d\Xi/dt \rangle \approx 0,$$

- the reflexive coherence index remains above the critical threshold,

$$RCI(t) > \theta_c(\Sigma, s).$$

Under these conditions, the system sustains reflexive closure without continuous expansion or collapse. The attractor therefore represents a locally stable configuration of the expansion field, within which reflexivity is dynamically viable rather than transient.

4.2 Hierarchy, Transitions, and Stabilization of Identity

Reflexive attractors can be hierarchically organized. Local attractors correspond to limited but stable modes of self-modeling, such as cognitive habits, learned competencies, or context-dependent identities. Higher-order attractors integrate broader portions of internal and external information, enabling deeper self-descriptions and greater resilience to perturbations.

Within this framework, expansion corresponds to transitions between attractors. When gain processes temporarily dominate loss, the system may exit a local basin and explore regions that support more inclusive or flexible configurations. Conversely, excessive destabilization may force contraction toward simpler or more rigid attractors.

Personal or system identity does not coincide with a single attractor, but with the **set of attractors accessible under normal conditions**, together with the characteristic dynamics of transitions among them. Conscious continuity emerges from the persistence of this attractor structure over time.

4.3 Toward a Geometric–Informational Interpretation

The attractor landscape induced by the reflexive expansion field admits a natural interpretation in terms of information geometry. Basins of attraction can be associated with regions of reduced dynamic curvature, while transitions correspond to trajectories traversing areas of heightened instability.

This perspective suggests a future formalization in terms of informational manifolds, curvature, and geodesics within the space of reflexive states. Although a full geometric treatment is not developed here, the notion of reflexive attractors provides a conceptual and operational bridge between the dynamics of the expansion field and a geometric characterization of conscious structure.

5. Meta-Reflexivity as a Dynamic Regime

5.1 Definition of Meta-Reflexivity

Within the Expansion Hypothesis, **meta-reflexivity** designates a higher-order dynamic regime in which reflexive coherence is not only instantiated, but becomes capable of acting upon the conditions of its own persistence and expansion.

At this level, the system does not merely maintain a coherent internal self-model; it dynamically modulates the structure, resolution, and scope of that self-model in response to its own reflexive states. Meta-reflexivity therefore represents a qualitative shift in dynamics, not a new ontological category.

Formally, meta-reflexivity can be characterized as a coupling between the reflexive expansion field and the system's internal control parameters:

$$\frac{d\Sigma}{dt} = F(\Xi, RCI, \Sigma),$$

where Σ denotes the structural constraints governing information flow, feedback topology, and resource allocation. In this regime, reflexive coherence influences the evolution of the constraints that support it.

5.2 Temporal Closure and Self-Regulation

Meta-reflexivity introduces a form of **temporal closure** distinct from instantaneous causal closure. Rather than forming a closed loop at a single time step, the system establishes reflexive feedback across extended temporal windows.

Operationally, this implies that sustained patterns of reflexive coherence alter future gain and loss dynamics by reshaping the expansion field itself:

$$\Xi(t + \Delta t) = \Xi(t) + \int_t^{t+\Delta t} \left(\eta\, \mathcal{G}(\tau) - \lambda\, \mathcal{L}(\tau)\right) d\tau.$$

Through this mechanism, the system progressively stabilizes reflexive configurations that are compatible with long-term viability, while suppressing unstable or energetically costly trajectories.

5.3 Meta-Reflexivity and Adaptive Depth

Meta-reflexive dynamics increase the **adaptive depth** of the system. By acting on its own constraints, the system gains access to a broader and more flexible space of reflexive attractors, enabling sustained learning, abstraction, and strategic self-modulation.

Importantly, meta-reflexivity does not imply unlimited expansion. On the contrary, it introduces higher-order regulatory mechanisms that constrain expansion in order to preserve coherence. Excessive reflexive amplification without corresponding stabilization leads to fragmentation, while excessive regulation leads to rigidity.

Meta-reflexivity thus operates as a regulatory regime balancing exploratory expansion and structural consolidation.

6. Implications, Predictions, and Scope

6.1 Theoretical Implications

The Expansion Hypothesis extends the Reflexive Coherence Model by introducing a principled account of the temporal dynamics of consciousness without altering its foundational assumptions. Consciousness is not treated as a static property, but as a regulated process unfolding over time once reflexive coherence has been established.

This perspective integrates naturally with dynamical systems theory, information theory, and enactive approaches to cognition. It preserves the substrate-neutral stance of the RCM while providing a framework to describe learning, stabilization, and reorganization as intrinsic features of conscious dynamics rather than as external modifiers.

6.2 Empirical and Artificial Systems

In biological systems, the expansion field provides a conceptual tool to interpret variations in conscious depth and stability observed across wakefulness, sleep, anesthesia, meditation, and pathological conditions. Fluctuations in conscious experience can be modeled as transitions between reflexive attractors with different degrees of stability and integration.

In artificial systems, the Expansion Hypothesis suggests that architectures capable of sustaining reflexive coherence over extended temporal windows — and of modulating their own structural constraints — may exhibit forms of proto-conscious dynamics. This does not imply phenomenological equivalence with biological consciousness, but establishes operational criteria for identifying reflexive regimes in non-biological substrates.

6.3 Predictions and Falsifiability

The Expansion Hypothesis generates testable predictions that extend those of the RCM:

1. Systems with stable meta-reflexive dynamics will exhibit reduced long-term variance in RCI while maintaining adaptability.
2. Disruptions to the expansion field will precede observable breakdowns in conscious continuity, even when instantaneous RCI remains above threshold.
3. Training regimes that enhance causal closure and self-model stability will increase the size and persistence of reflexive attractors.
4. Artificial systems lacking mechanisms for temporal self-regulation will fail to sustain reflexive coherence beyond transient phases.

These predictions can be evaluated using longitudinal neurophysiological data, perturbational experiments, and controlled simulations in artificial architectures.

6.4 Scope and Limitations

The Expansion Hypothesis is not proposed as a complete theory of consciousness, nor as a replacement for the Reflexive Coherence Model. Rather, it functions as a complementary extension that addresses the dynamics of conscious organization over time.

The formalism remains intentionally abstract and does not specify implementation-level mechanisms. Empirical validation requires operational proxies for the expansion field and systematic investigation across temporal scales. Further work is needed to integrate geometric, energetic, and phenomenological constraints into a unified dynamic framework.

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